

Information Sciences & Technology: Human-Systems Integration Division



Visual Stability of Objects and Environments Viewed Through Head-Mounted Displays

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Definition of a Virtual Environment

A virtual environment is an interactive, virtual image display enhanced by special processing to convince its users that they are personally and directly physically immersed in a space other than the one they actually inhabit.

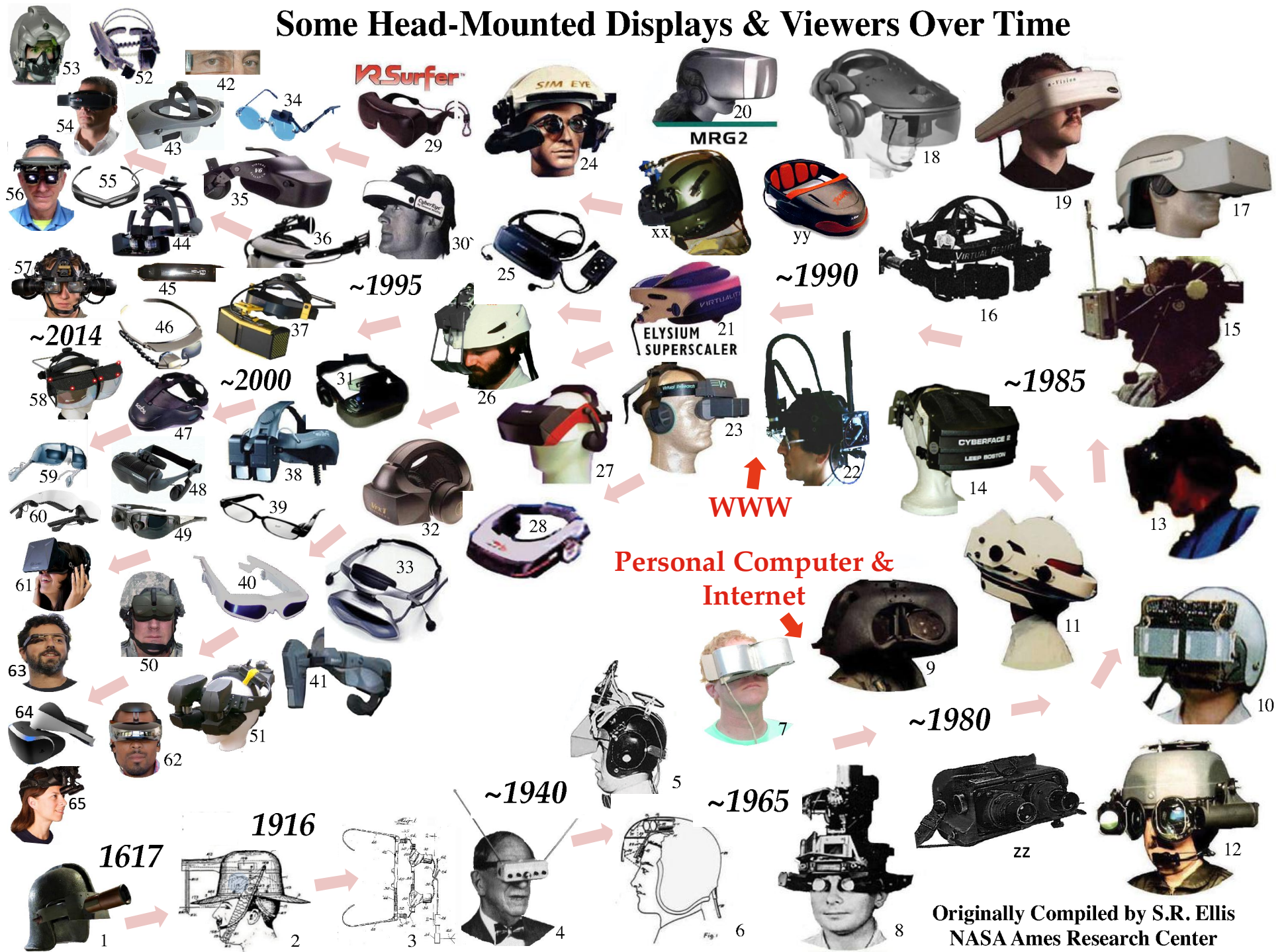


Ivan Sutherland's HMD Univ. of Utah

Ivan Sutherland's virtual environment *personal simulator*¹ circa 1965

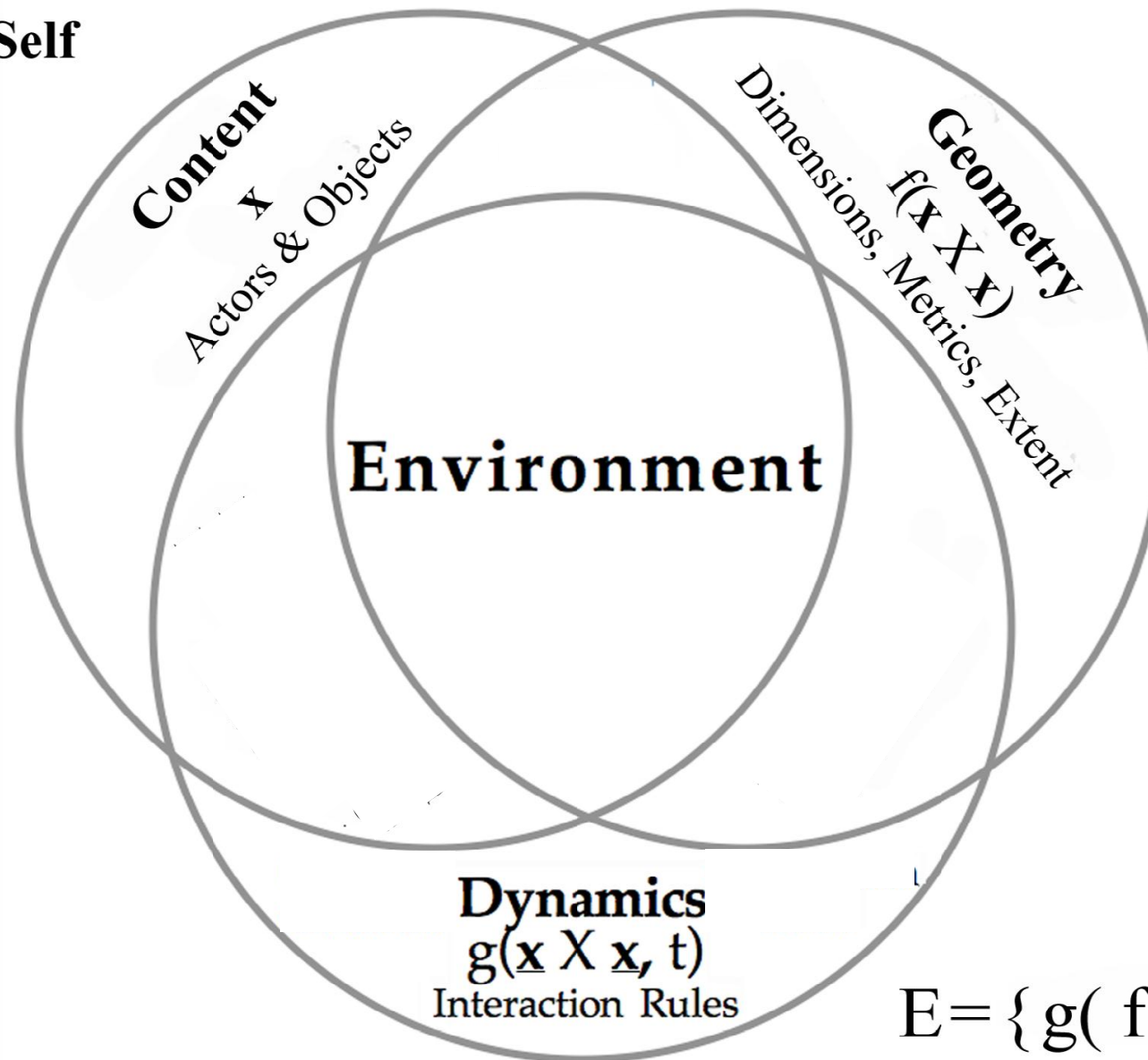
¹Haber, R. N. (1986). The simulation of high speed aircraft flight. *Scientific American*, 255,(July) 96-103.

Some Head-Mounted Displays & Viewers Over Time



Abstract Decomposition of an Environment

Self



$$E = \{ g(f(\mathbf{x} \times \mathbf{x}), t) \}$$

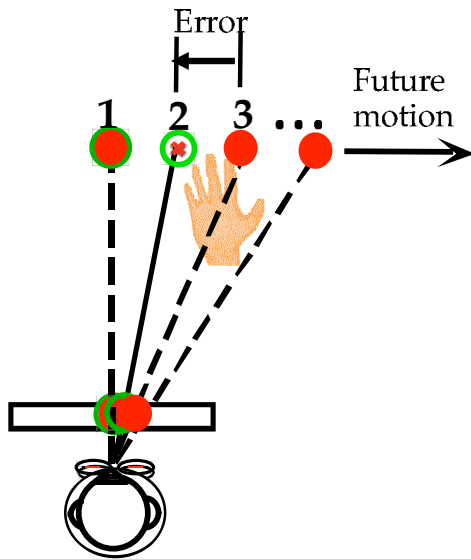
Example of Path Following

Latency ~380 ms



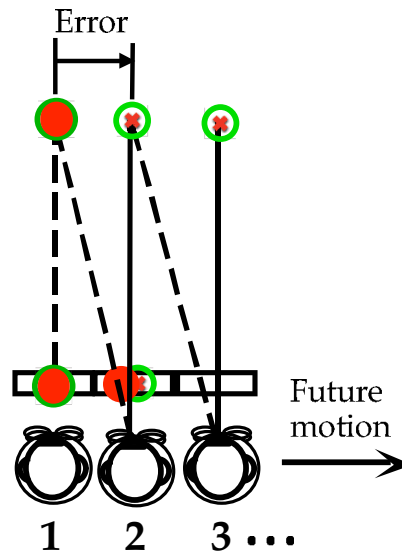
Intersensory Performance Effects of Latency in A Virtual Environment

Hand Translation



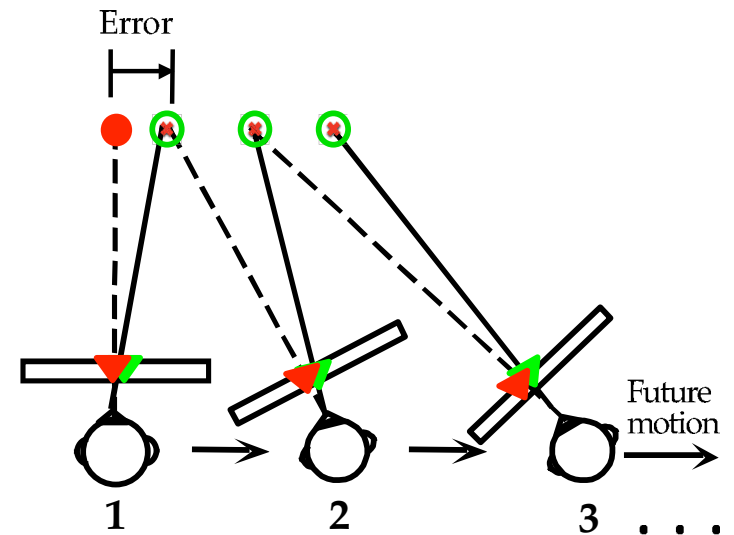
Error in the
direction of motion

Head Translation



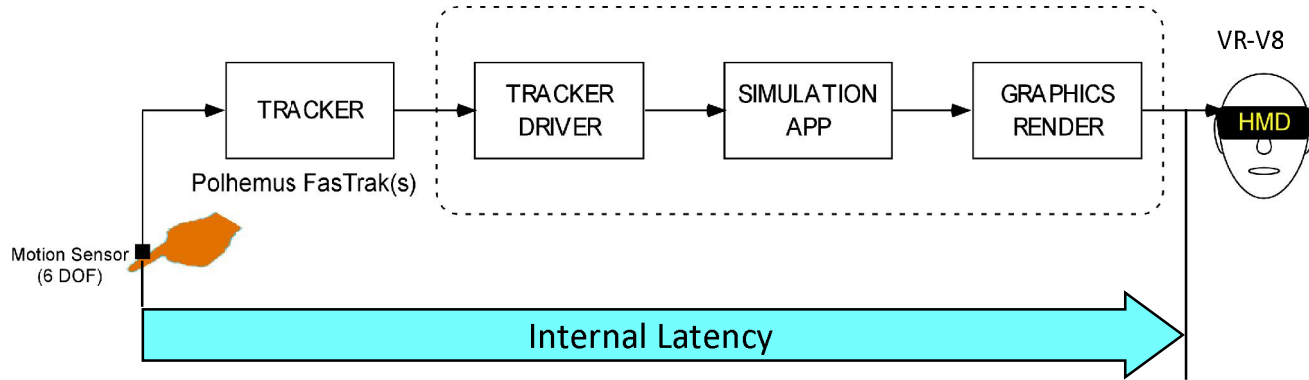
Error against the
direction of motion

Head Translation and Rotation



Superposition of errors
both in and against the
direction of motion for
translation and rotation

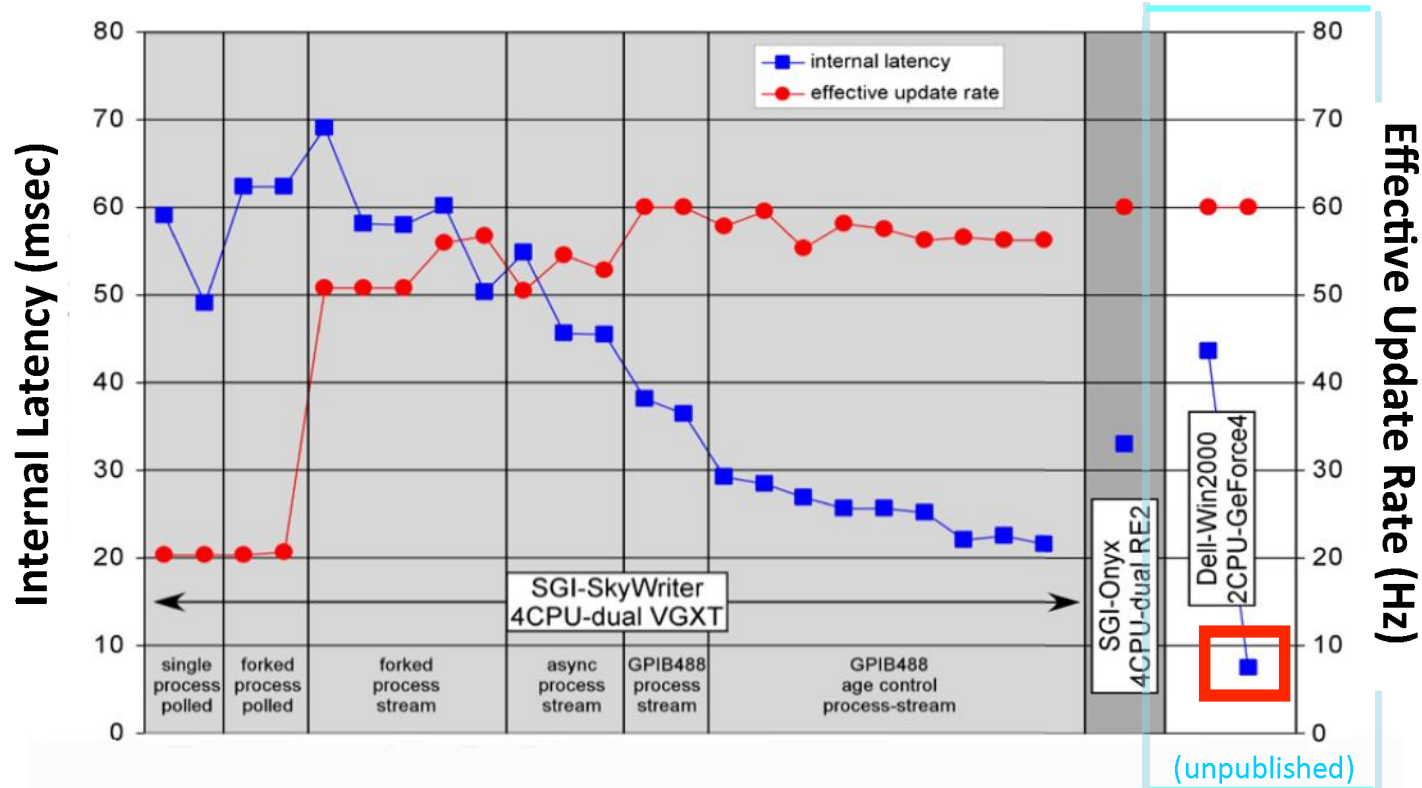
System Latency with some Polhemus-based Systems



$$E(\tau_{end-to-end}) = \sum_{i=1}^N E(\tau_i)$$

$$\sigma^2_{end-to-end} = \sum_{i=1}^N \sigma_i^2$$

Measure and Model



Example of Path Following Low Latency ~1994



Some Characteristics of the Head Mounted Display System Used Or Where We Were ~ 1990? (at least some of us)

Weight 0.77 – 1.1 kg Thank you Sony!

Visual

| | |
|-----------------------|--|
| Resolution 1024 X 768 | → ~700 X 525 check VIEW hardware |
| Brightness min/max | 6/68 cd/m ² ~ w/r see-thru background |
| FOV | 20°-32° diameter |
| Contrast(Michelson) | 0.6 – 0.8 ~ w/r see-thru background |
| Color | Monochrome |
| Accommodative Demand | 1 diopter (adjustable) |
| Stereo resolution | ~2-3 arcmin |
| Stereo overlap | 100% |
| IPD | 60 -78 mm |

Tracking & Rendering Polhemus Fastrak/vairous SGI/PCs

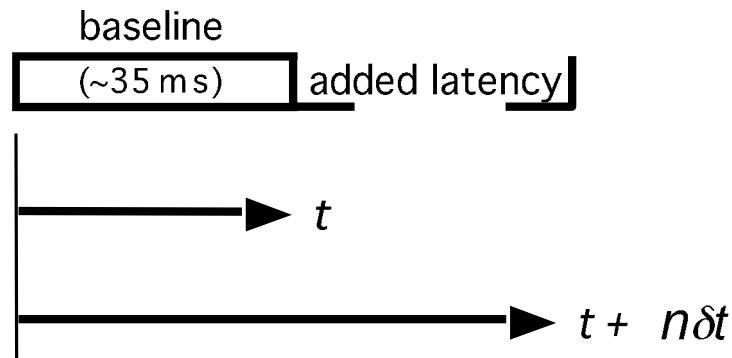
| | |
|----------------------|----------------------|
| Accuracy | ~ ±5 mm, 1-2° |
| Resolution | < 1 mm, < 0.24° |
| Position sensing: | 120 Hz |
| Frame (Update) rate: | 60 Hz |
| Latency | ~45 ms (now 8-25 ms) |

User Interface

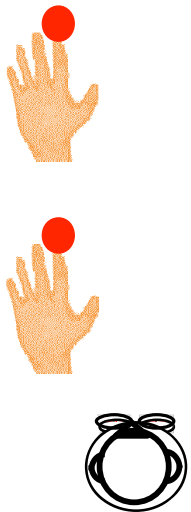
None: voice to computer operator/HMD assistant

Latency Discrimination in Virtual Environments

Two-Alternative Forced Choice Discrimination



$t = \{35, 101, 205\}$, $\Delta t = 16.7$ ms
 $n = \{0, 1, 2, 3, 4, 5, 6\}$



- Method of constant stimuli
- Randomized blocks each base t (224 judgments)
- Sub-blocks each increment Δt (32 judgments)
- 3 repetitions per subject
- Metronome-paced movement 0.5 Hz

2nd Condition

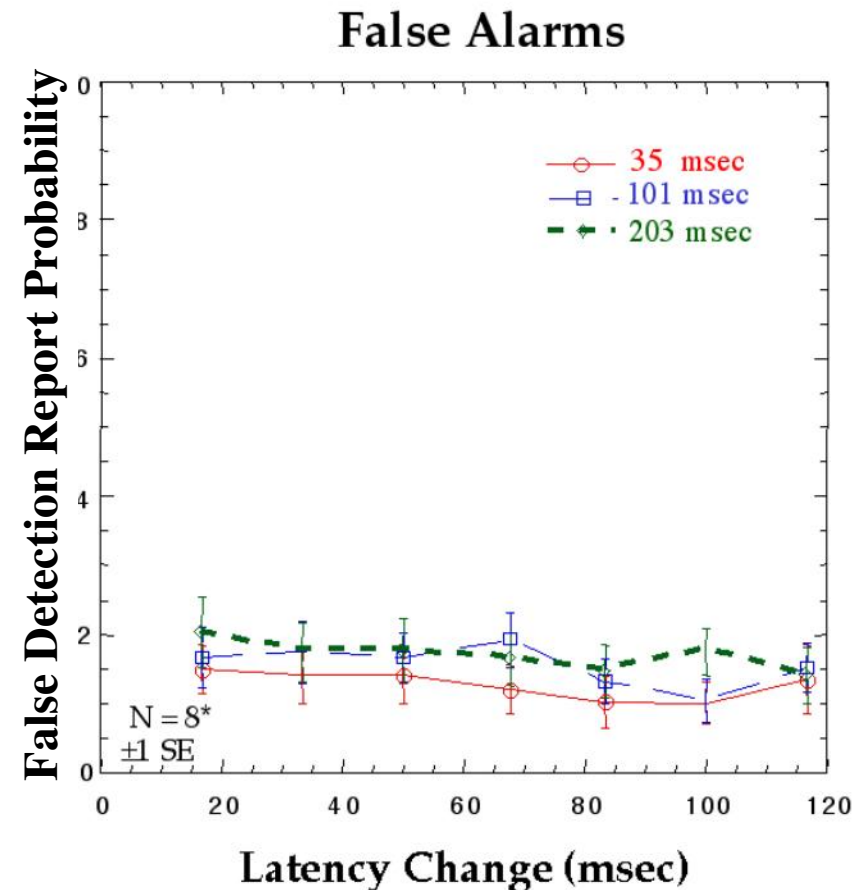
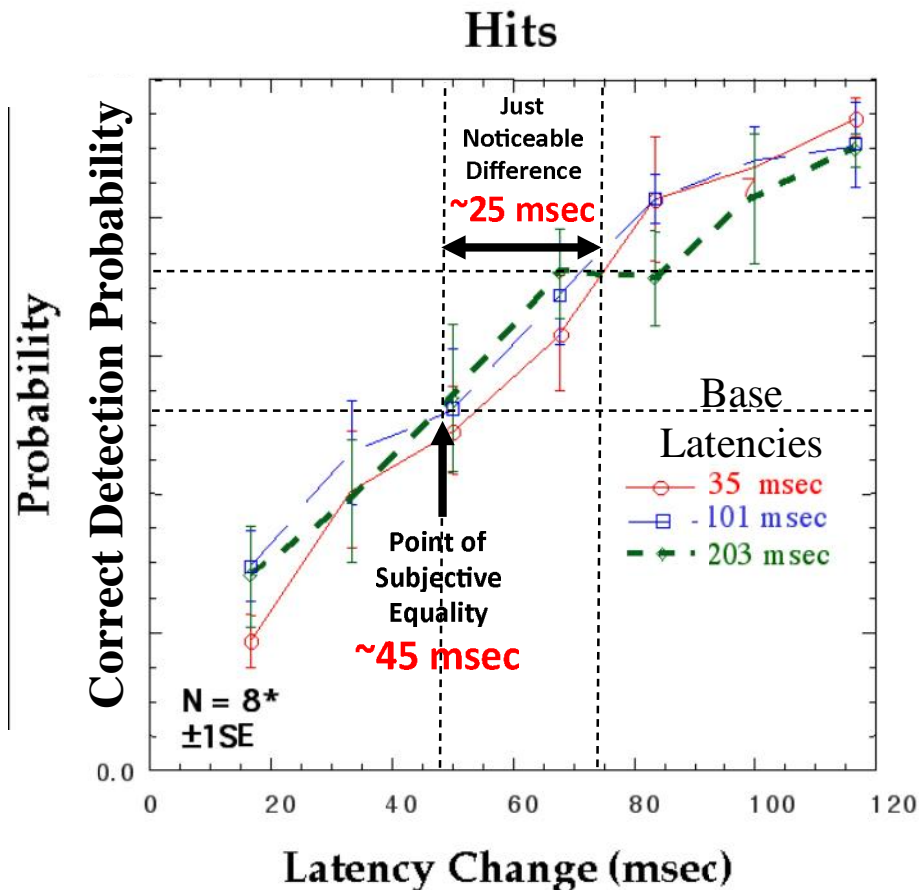
| | | t | $t+n\Delta t$ |
|---------------|---------------|------|---------------|
| 1st Condition | $t+n\Delta t$ | .125 | .375 |
| | t | .375 | .125 |

Catch trials

(Ellis, Young, Ehrlich ,
& Adelstein, 1999)

Observer Detection of Changes of Latency during Paced Hand Movement of Virtual Objects

No Webers Law: $\Delta t_l/t_l$ not constant!

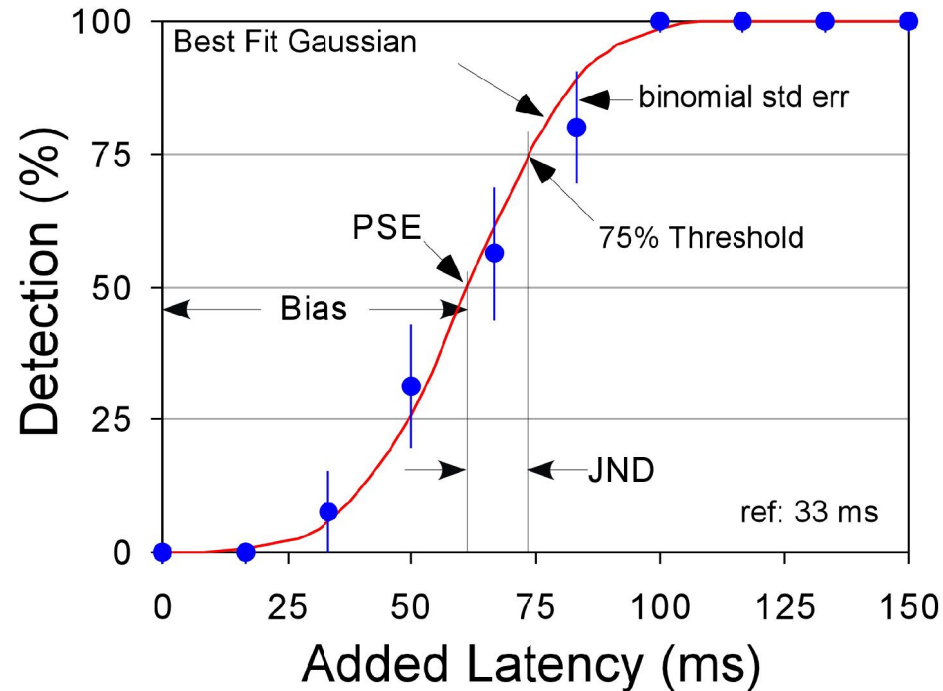


*Practiced observers using an occluding HMD

Ellis, Stephen R. , Young, Mark J. , Ehrlich, Sheryl M., and Adelstein, Bernard D. (1999) Discrimination of changes of latency during voluntary hand movement of virtual objects. Proceedings of HFES. pp. 1182-1186.

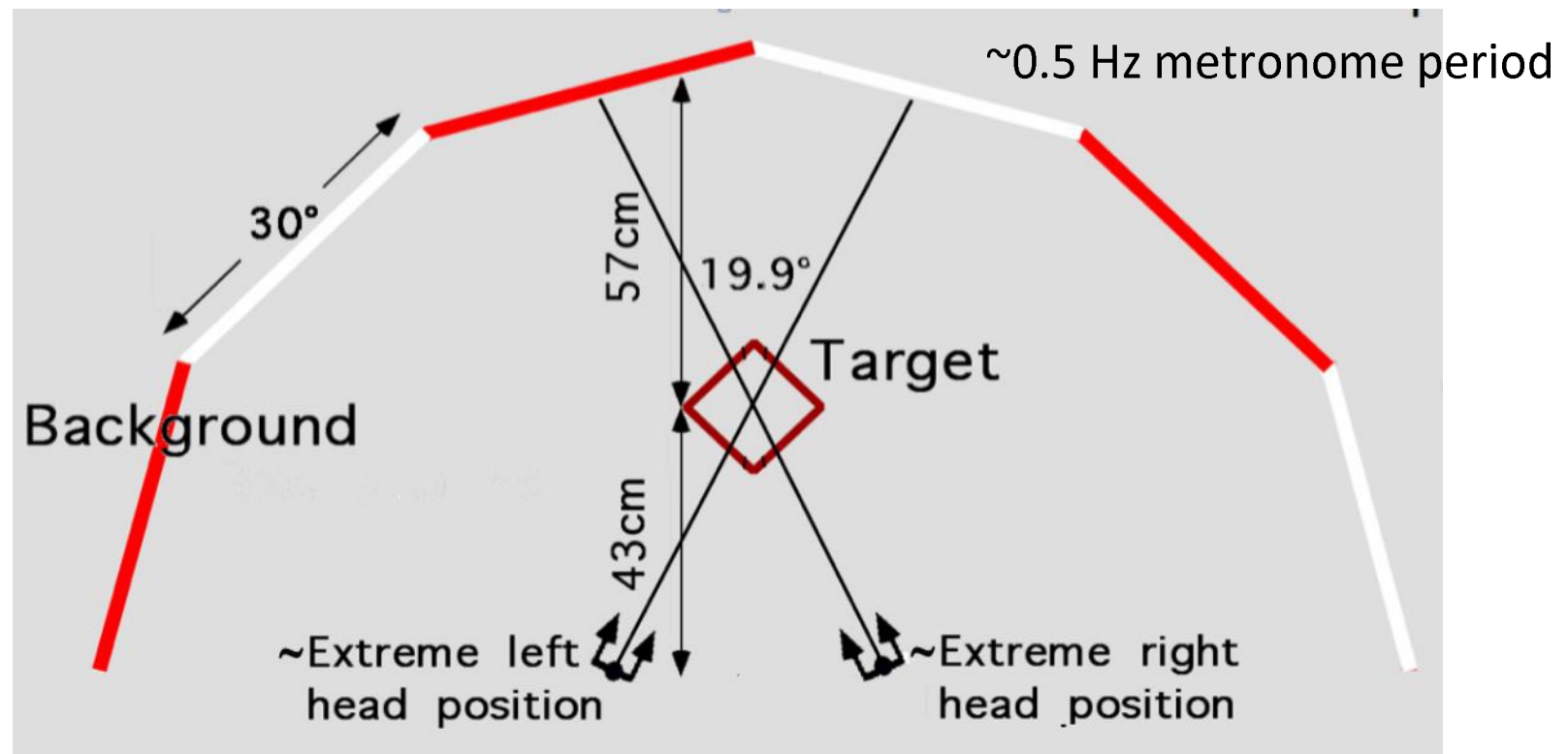
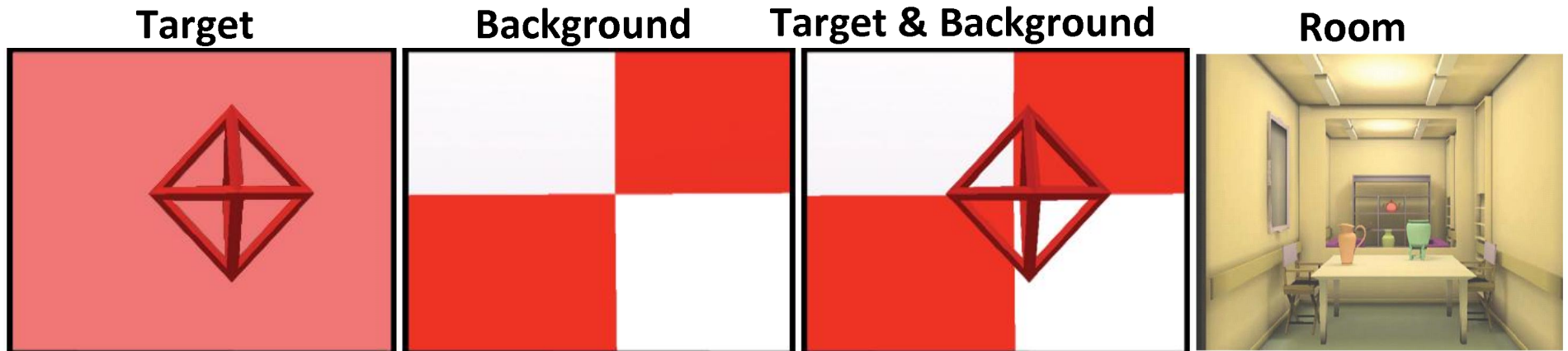
Latency Detection One Subject Making Head Rotations

Data Analysis Procedure

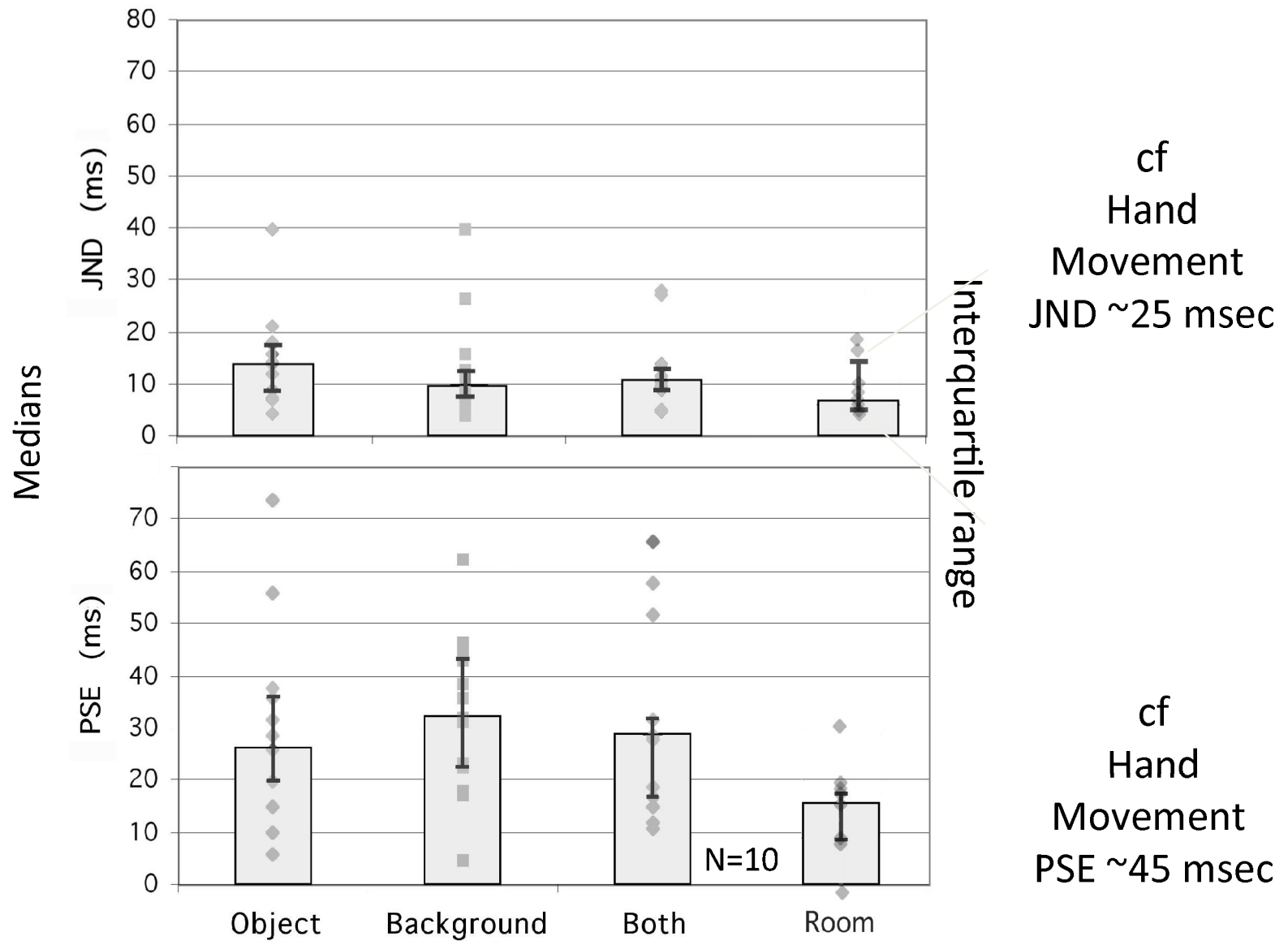


- Accumulated responses from 10 ascending 10 descending runs
- Probit Analysis → Gaussian Quartiles → PSE & JND

Latency Discrimination During Head Movement: Graphic Models



Latency Discrimination during Head Movement



HIGH RESOLUTION: WHERE ARE WE?

DK1 100% overlap

640x480 @ 110 degrees

~6 pixels / degree

DK2

960x1080 @ 100 degrees

~10 pixels / degree

100% overlap Vive

1080x1200 @ 105 degrees

~10 pixels / degree

VRelia Pro G1

1920x1080 @ 123 degrees

~15 pixels / degree

Sony Morpheus

Courtesy and after Mark Miné, Dir. Disney, Disney Research

Some Imagined Performance Specs for HMDs but especially for dream Augmented Reality

